Water in the West: A Look at the 21st Century

Aquatic Professionals
February 12, 2008
Fort Collins, Colorado

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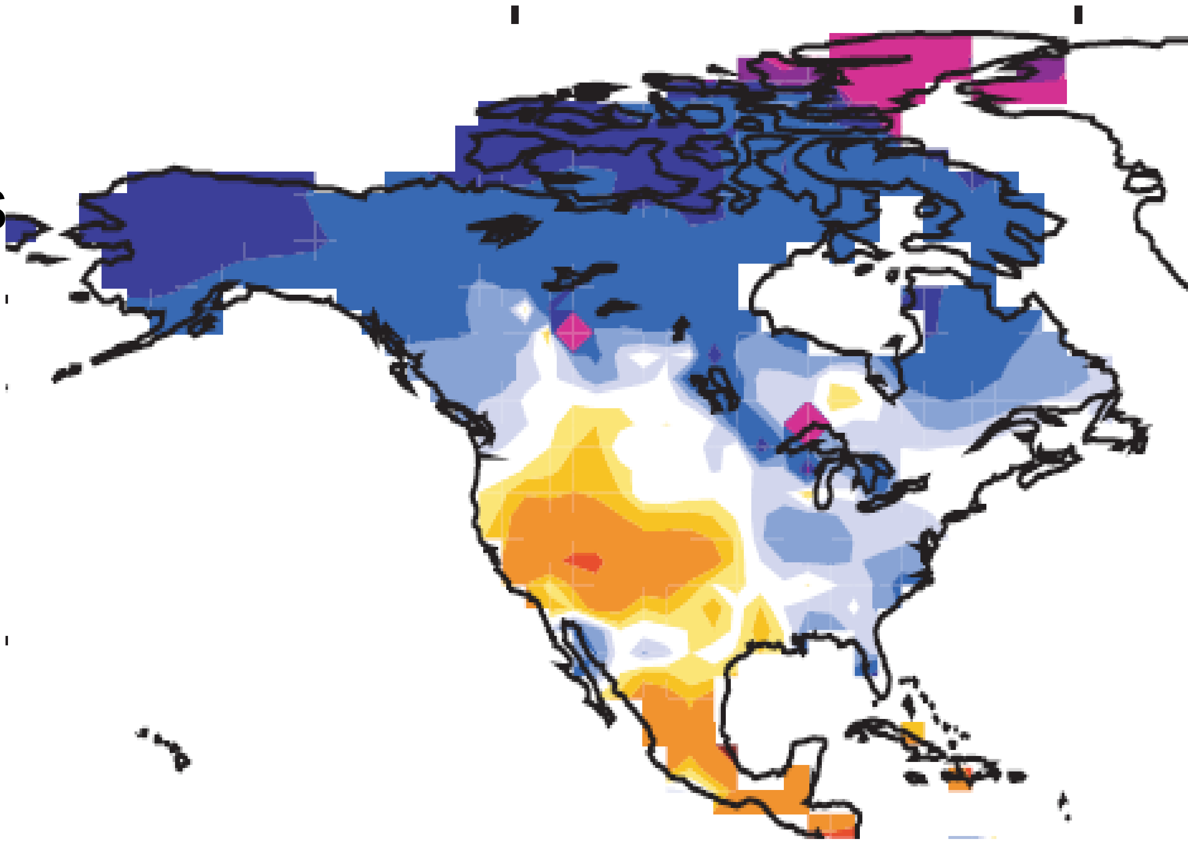

Runoff 2050: -20%

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Overview

- Climate Setting: Projections, Trends
- Hydro Cycle Changes
- Colorado River Case Study
- Conclusions

"Long term, I'm worried about global warming—short term, about freezing my ass off."

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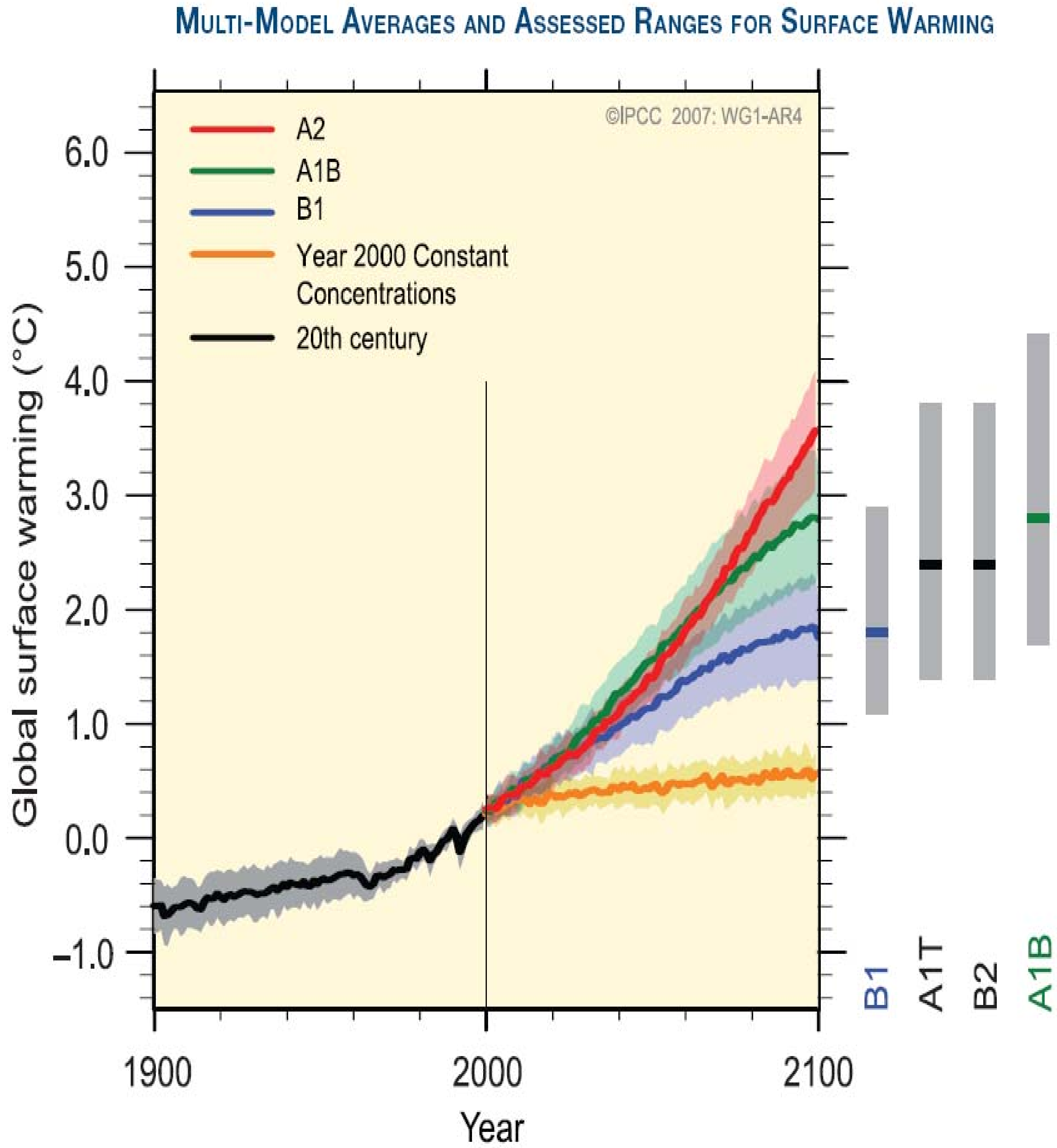
The climate has started to change, and will change rapidly throughout the 21st century.



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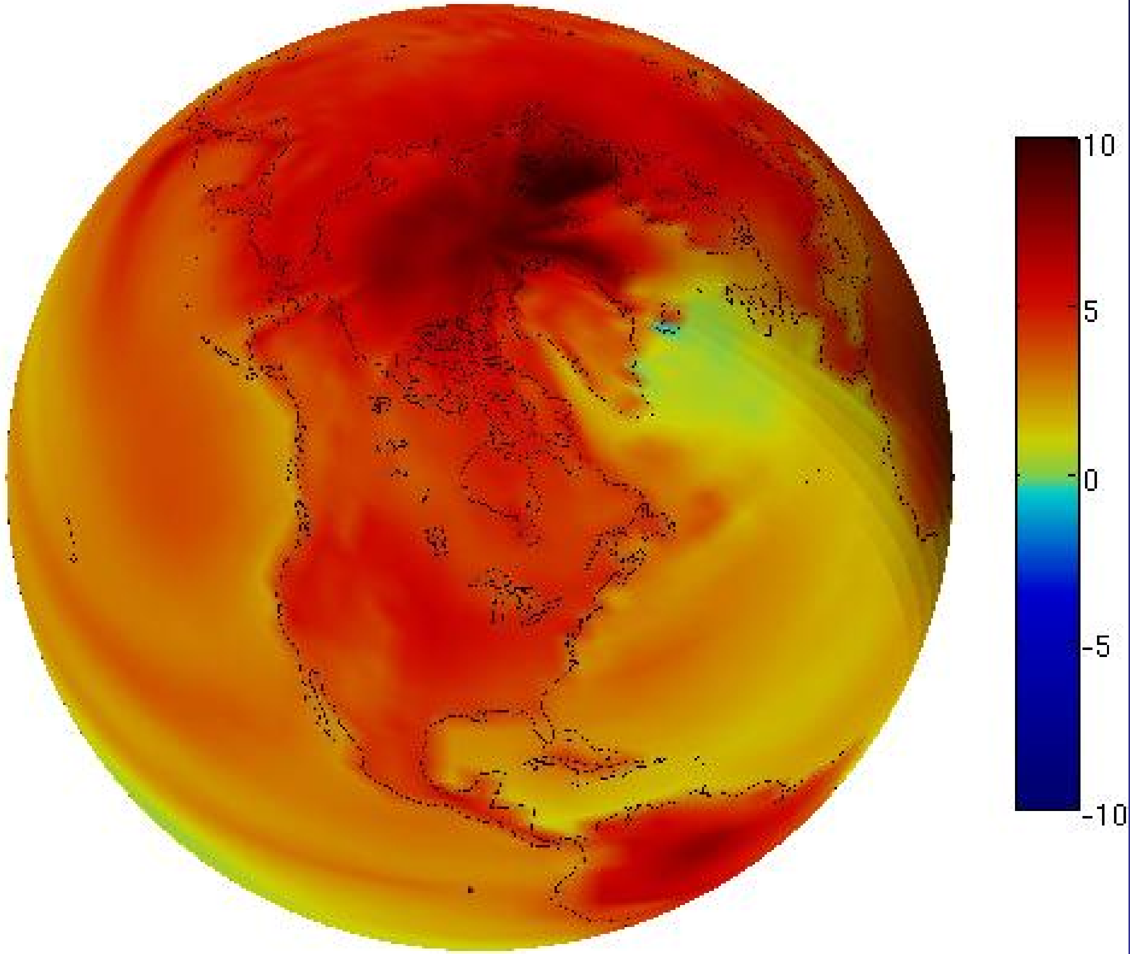
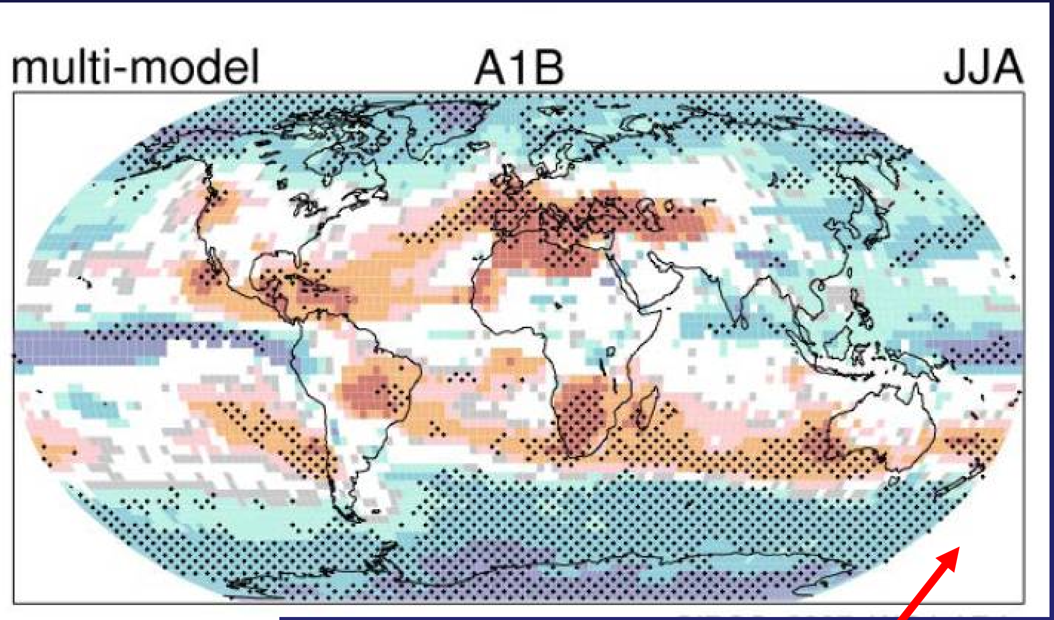
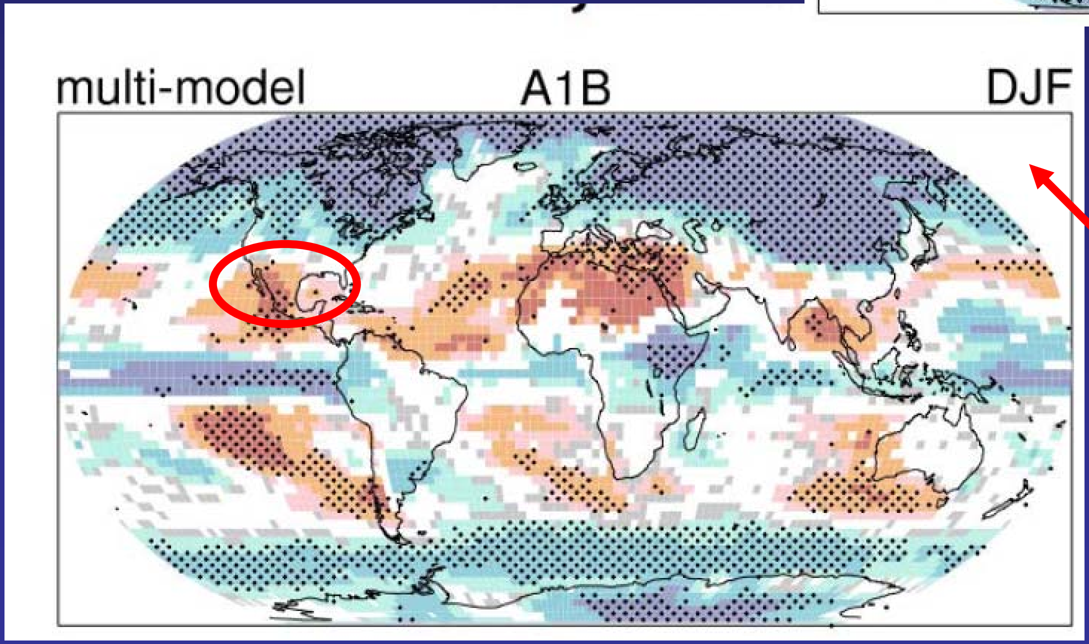
Model projection for 2100



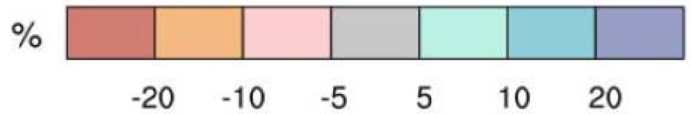
Continents Warm 50% more than oceans

IPCC AR4 Projected Patterns of Precipitation Changes 2007





- Summer and Winter



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Another Study

- PRELIMINARY Results -- lots of additional analysis required. Models are not predictions.
- 10 to 30% Less Runoff
- About ¾ of Models Agree
- Decreases in runoff due to temperature increases, perhaps small precipitation declines
- Dryness consistent with world-wide poleward movement of deserts from ~30 N/S Latitude

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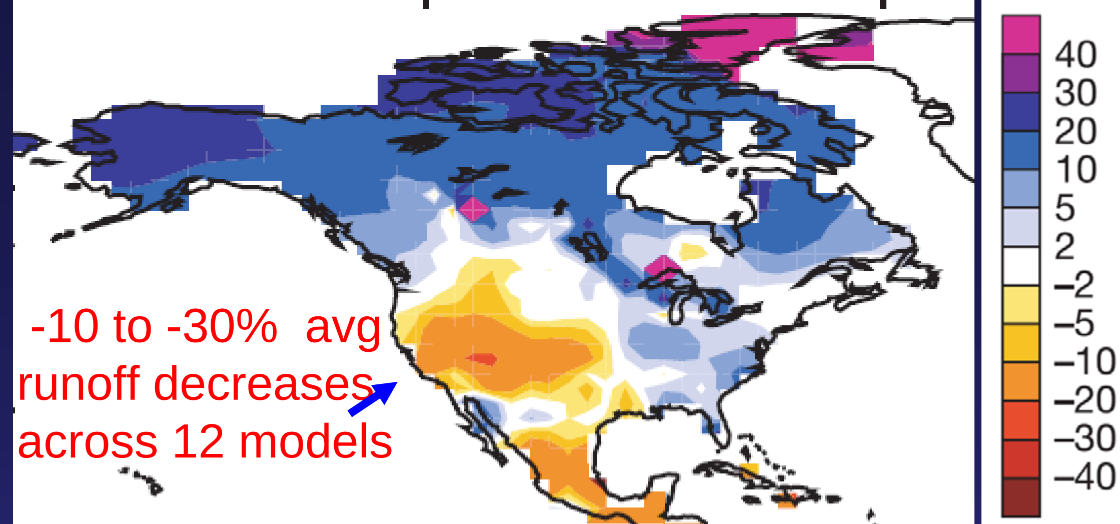
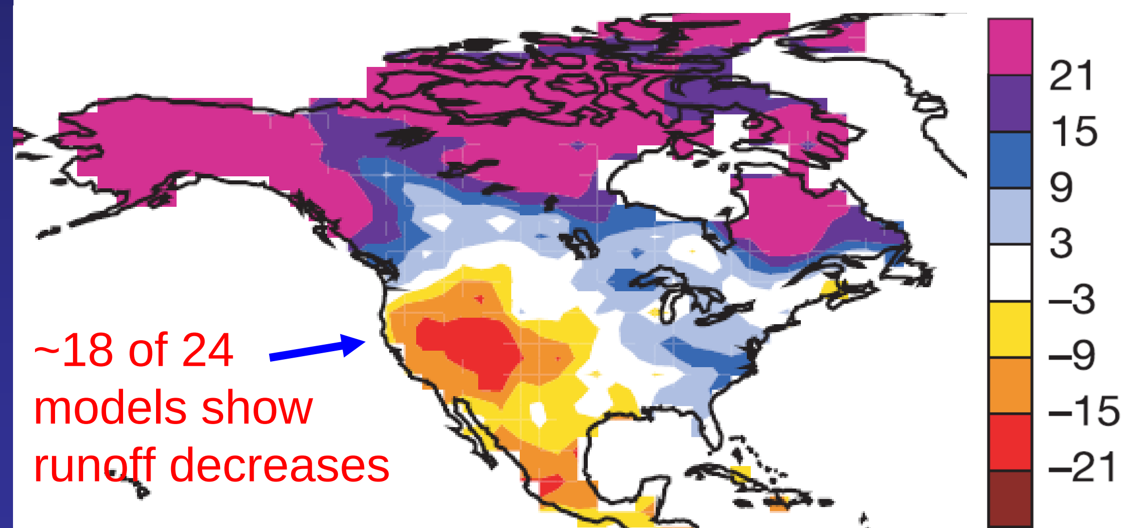


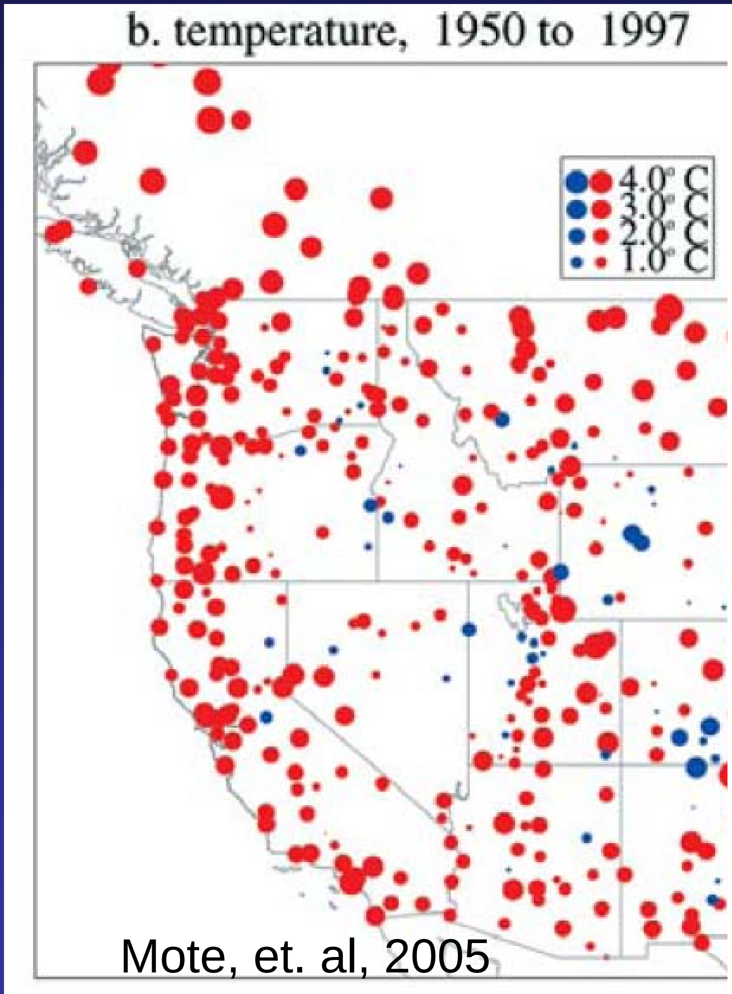
Relative Change in Runoff 2041 to 2060 relative to 1900-1970 Runoff from 12 Models

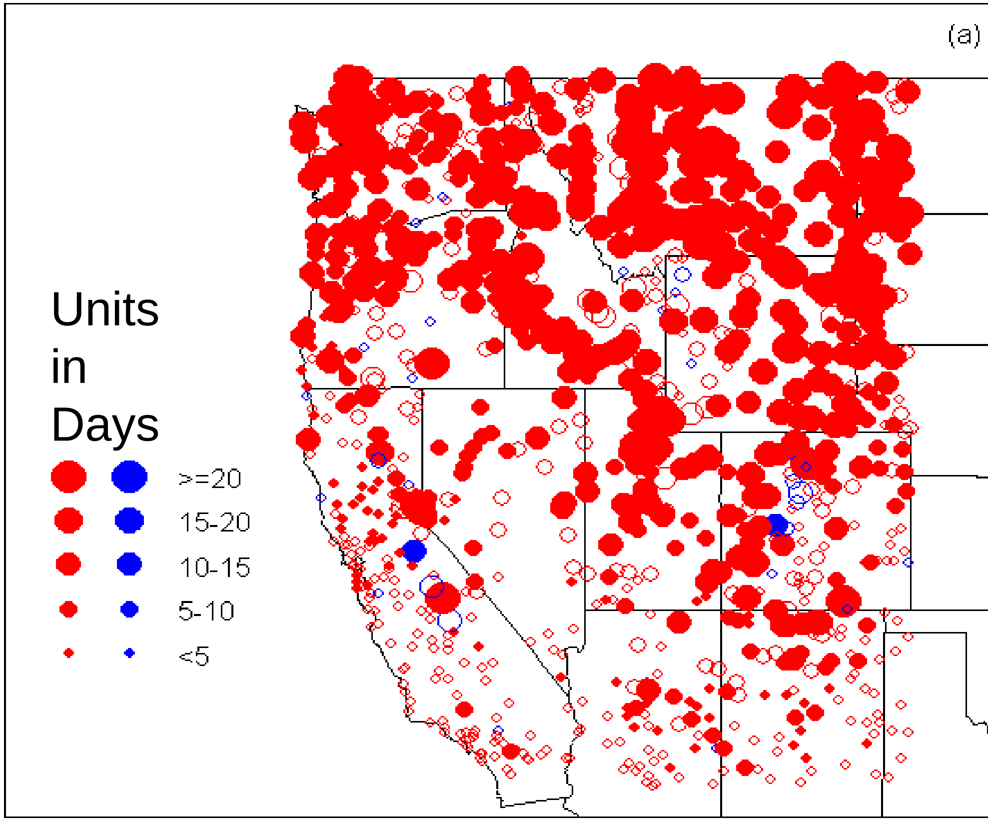


Number of Models Runs showing a positive change minus number showing negative change. ("-" = dry agreement)

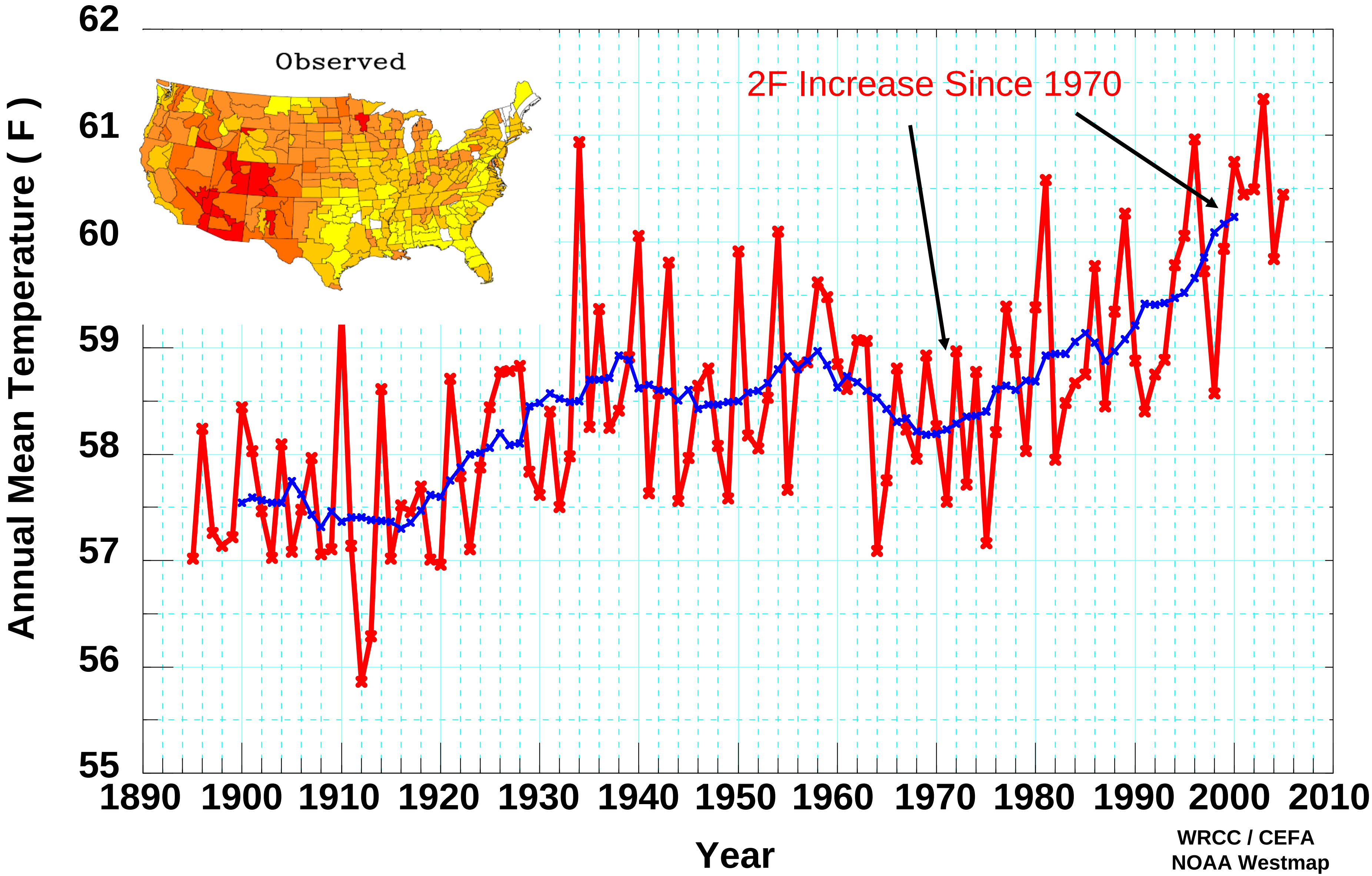
Milly, et al, Nature 2005

Trends in Temperature



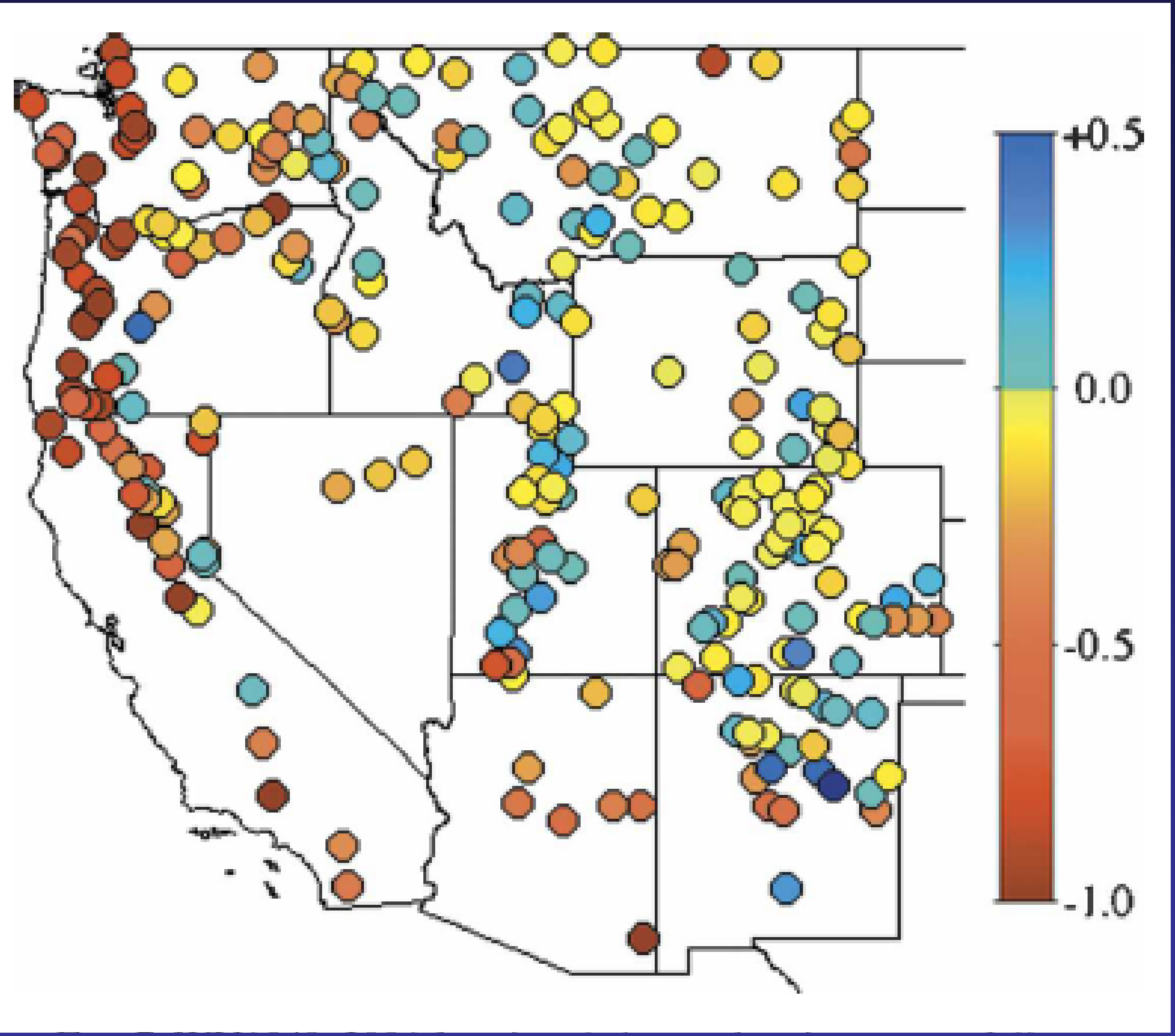


Lower Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.



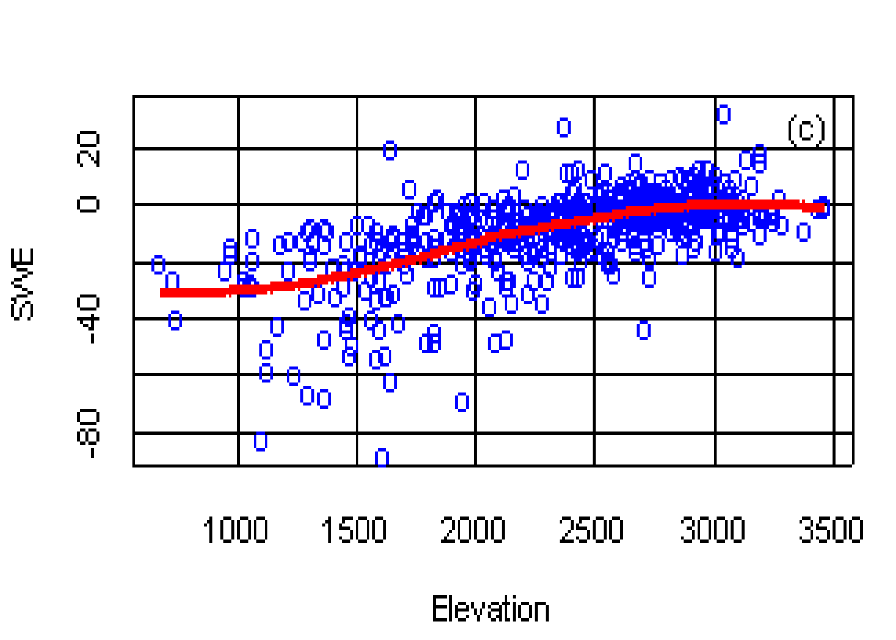
Kelly Redmond, DRI

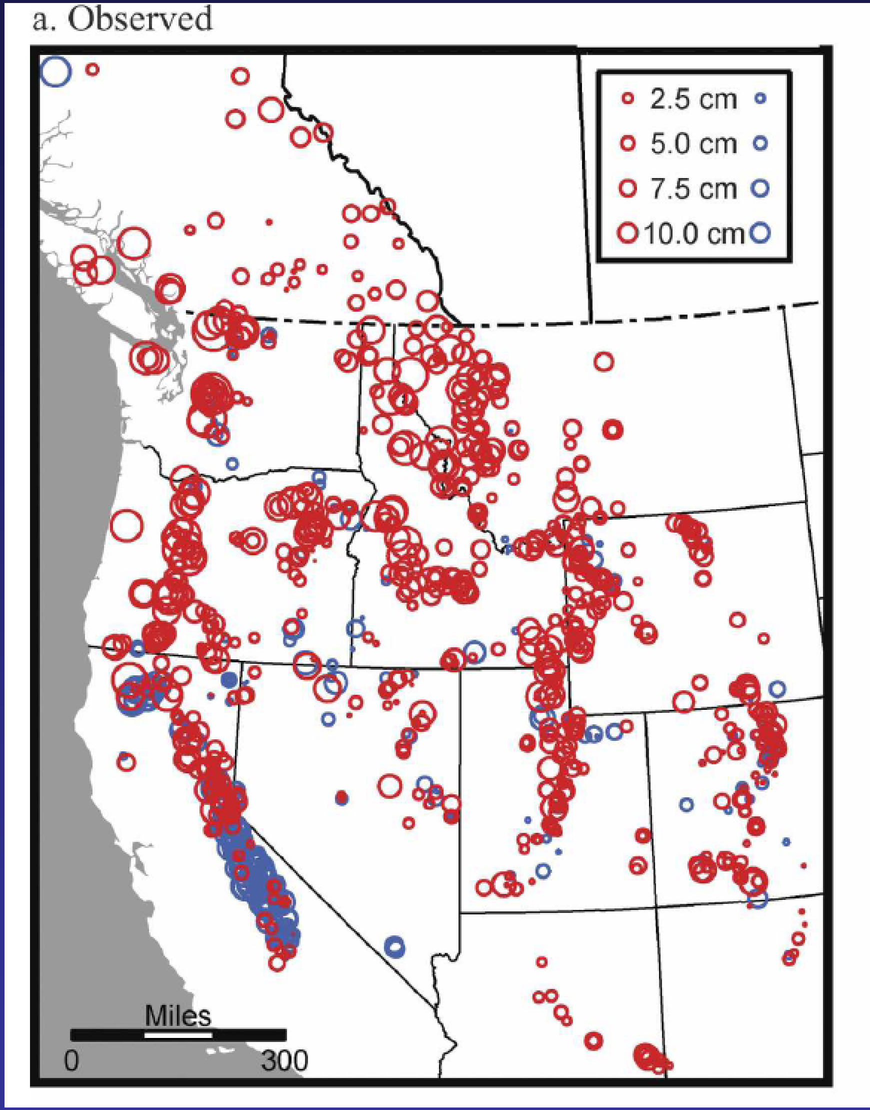
Changes in Snow vs. Rain



Knowles, et. al, 2006

- Snow Water Equivalent Trends, 1960-2002





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Phil Mote, 2006

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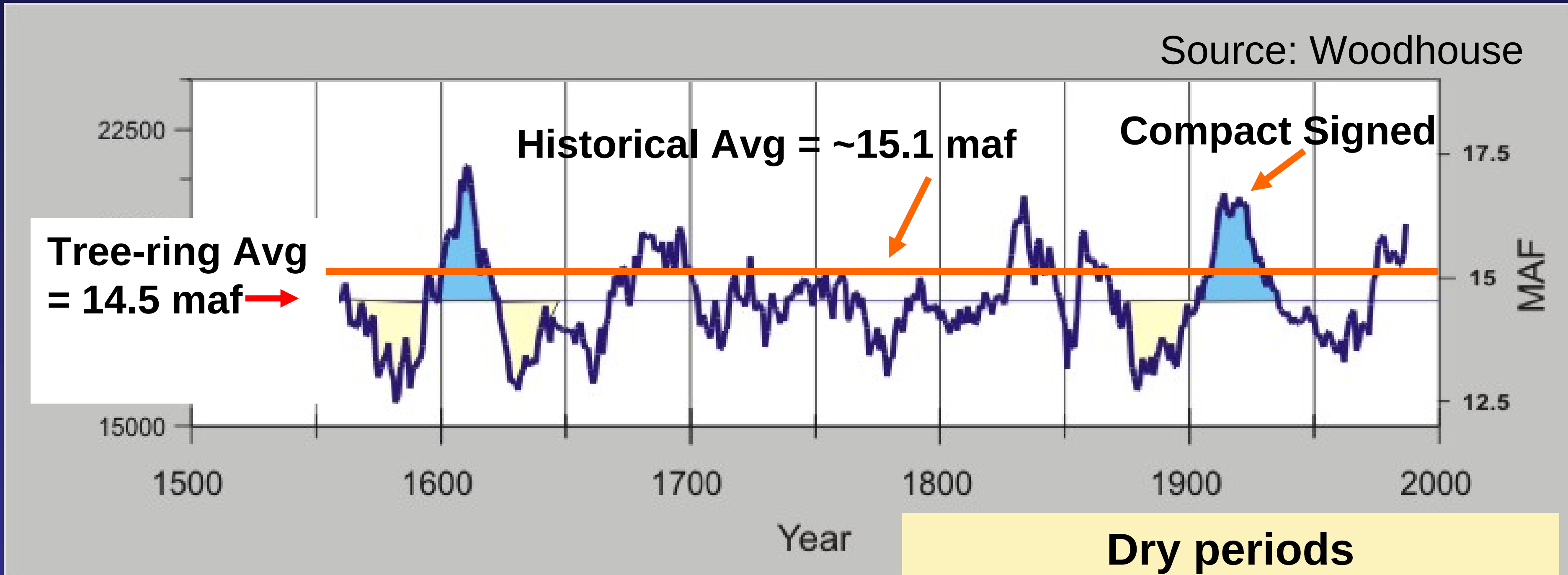
Hydrologic Cycle Changes in a Warmer World

- Enhanced hydrologic cycle
  - Higher Temps Increase Atmosphere Moisture holding capacity
  - Higher Temps imply Globally Increased Evaporation
  - Precipitation must increase globally (But not necessarily regionally)
  - More Intense Precipitation - Floods
  - More Intense Drying - Drought
    - Mid-Continental Summertime Drying
    - Increased Evaporation Will Increase Water Demand
  - More Rain, Less Snow
  - Earlier Spring Runoff

Woodhouse, Meko, Gray New Reconstruction of Lees Ferry Streamflow, 20-year moving average, 1536-1997



Dry periods

Lowest 20-yr avg.	Lowest 25-yr avg
1573-1592 (1)	1622-1646 (1)
1622-1641 (3)	1623-1647 (2)
1870-1889 (4)	1878-1902 (3)
1953-1972 (35)	*1953-1977 (28)*

Note that 20th Century Dry Periods are not especially dry….

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Source: Woodhouse

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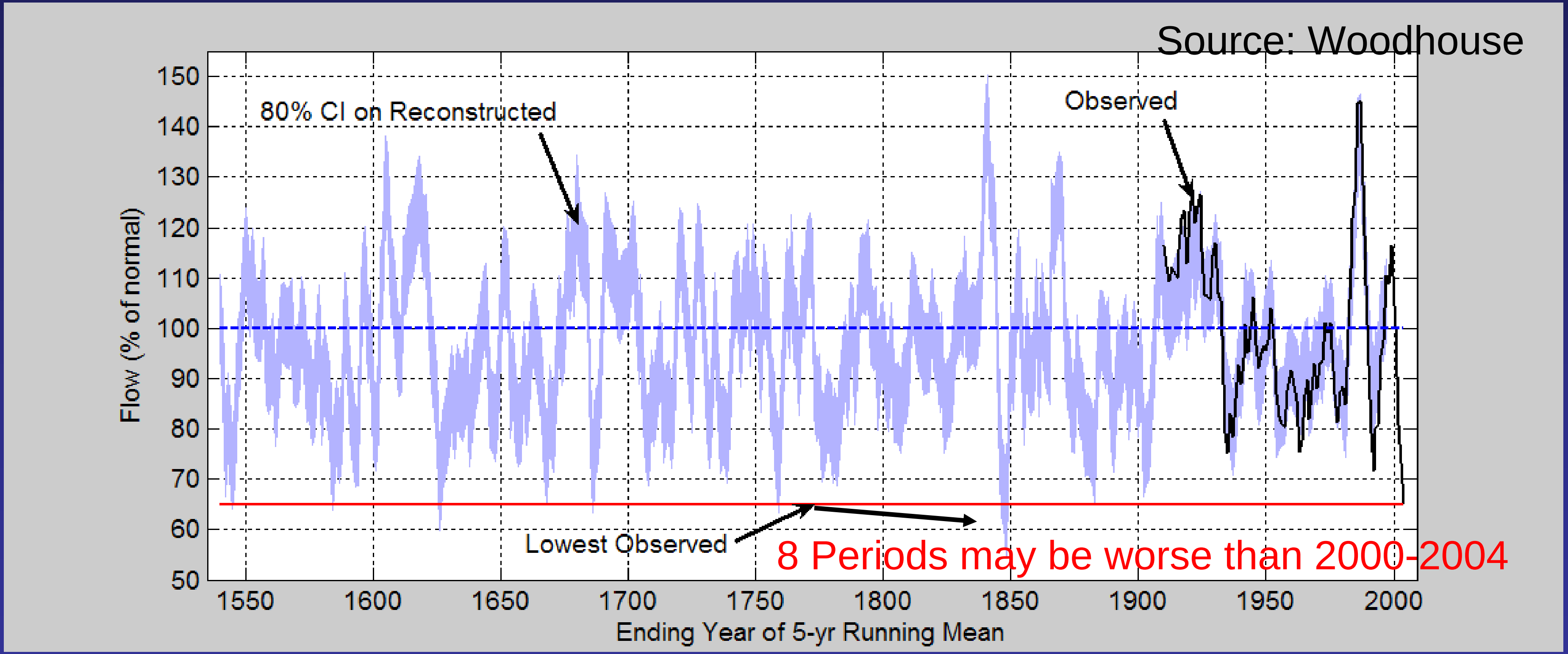
Lees Ferry Reconstruction, 1536-1997
5-Year Running Mean

Assessing the 1999-2004 drought in a multi-century context



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Source: Woodhouse

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2004 Snowpack Vanishing Act

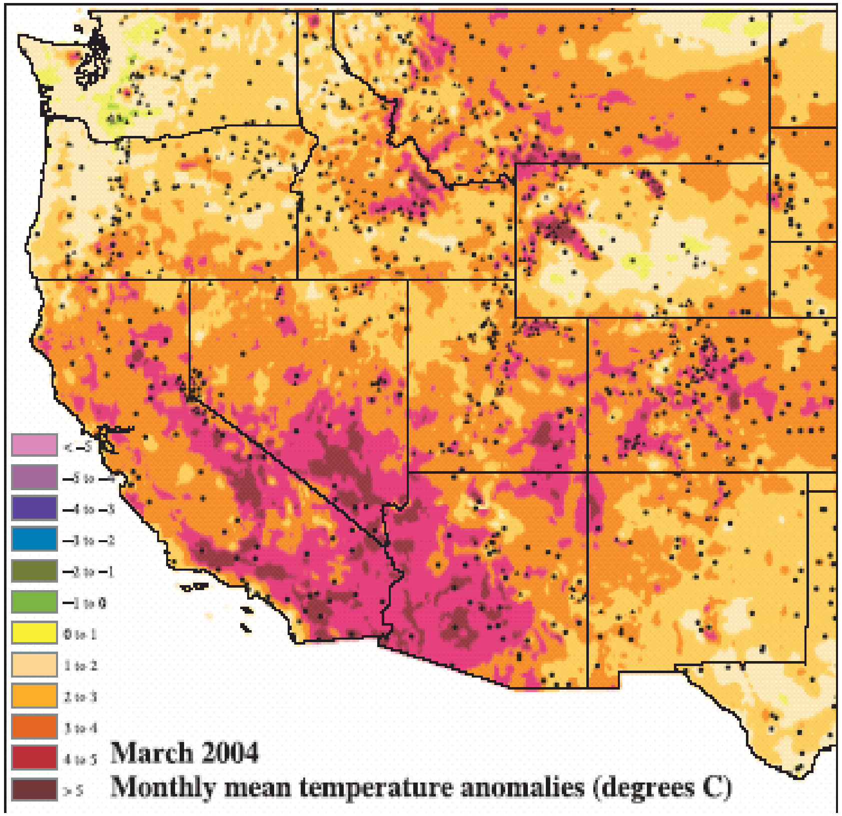


Fig. 1. March 2004 observed monthly mean temperature anomalies in degrees Celsius. NRCS SNOTEL sites are shown as triangles, and NWS sites are shown as circles. Contours are derived using the PRISM system (http://www.ocs.orst.edu/prism/).

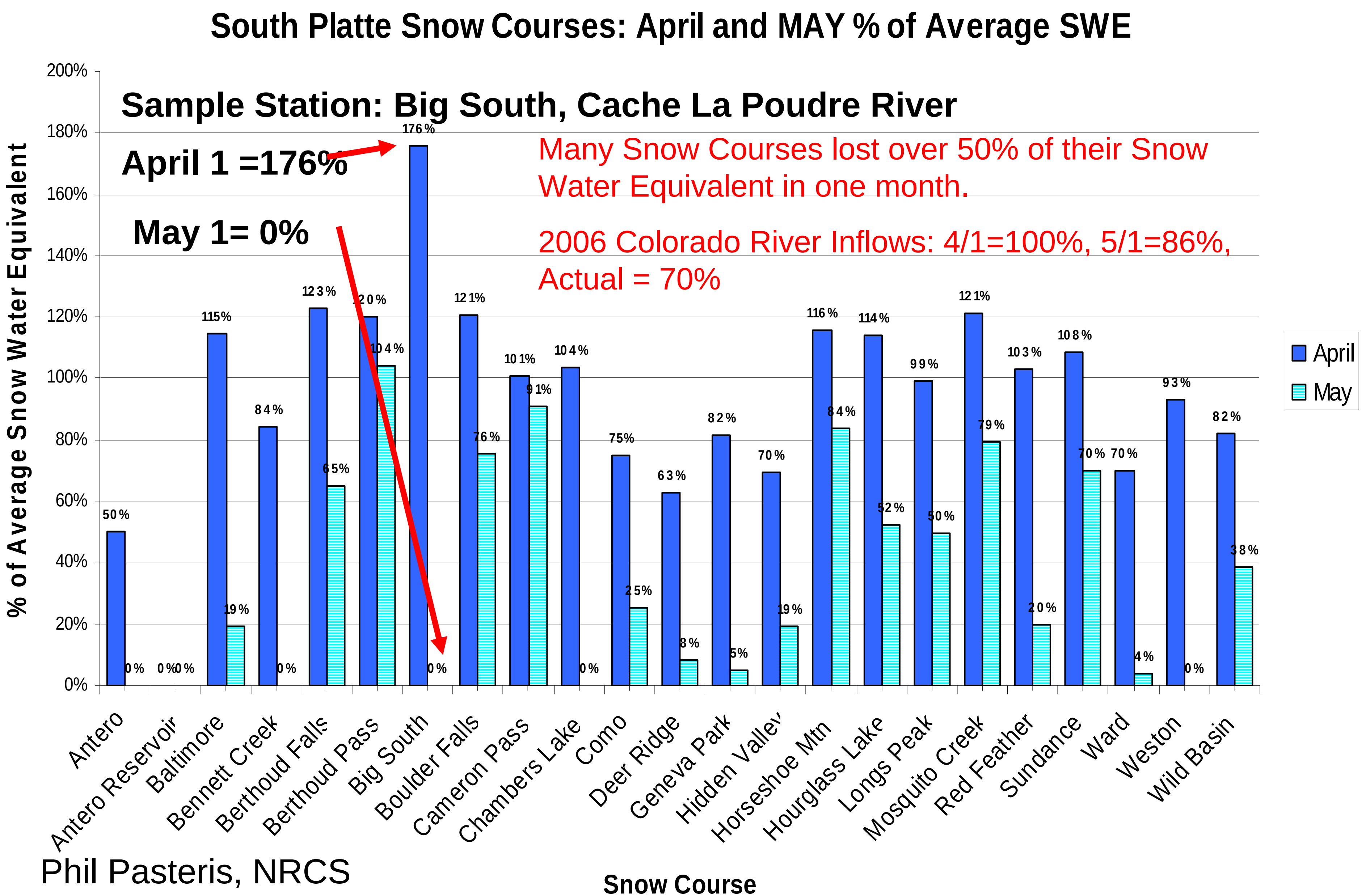
Table 1. Summary of Mountain Snowpack (Snow Water Equivalent) Changes Between 1 March and 1 April 2004.

State/Area	*Statewide % of Average, 1 March 2004*	*Statewide % of Average, 1 April 2004*	*Statewide % of Average, Change*
Arizona	74	22	-51
Sierra/Tahoe	113	70	-35
Colorado	90	64	-26
Idaho	105	81	-25
Montana	93	78	-16
Nevada	118	64	-54
New Mexico	80	37	-43
Oregon	126	96	-30
Utah	109	70	-39
Washington	93	86	-7
Wyoming	91	71	-19

Rapid snowpack reduction. Record warmth and dryness combine in March 2004. (Pagano, Pasteris, Redmond, Dettinger, EOS)

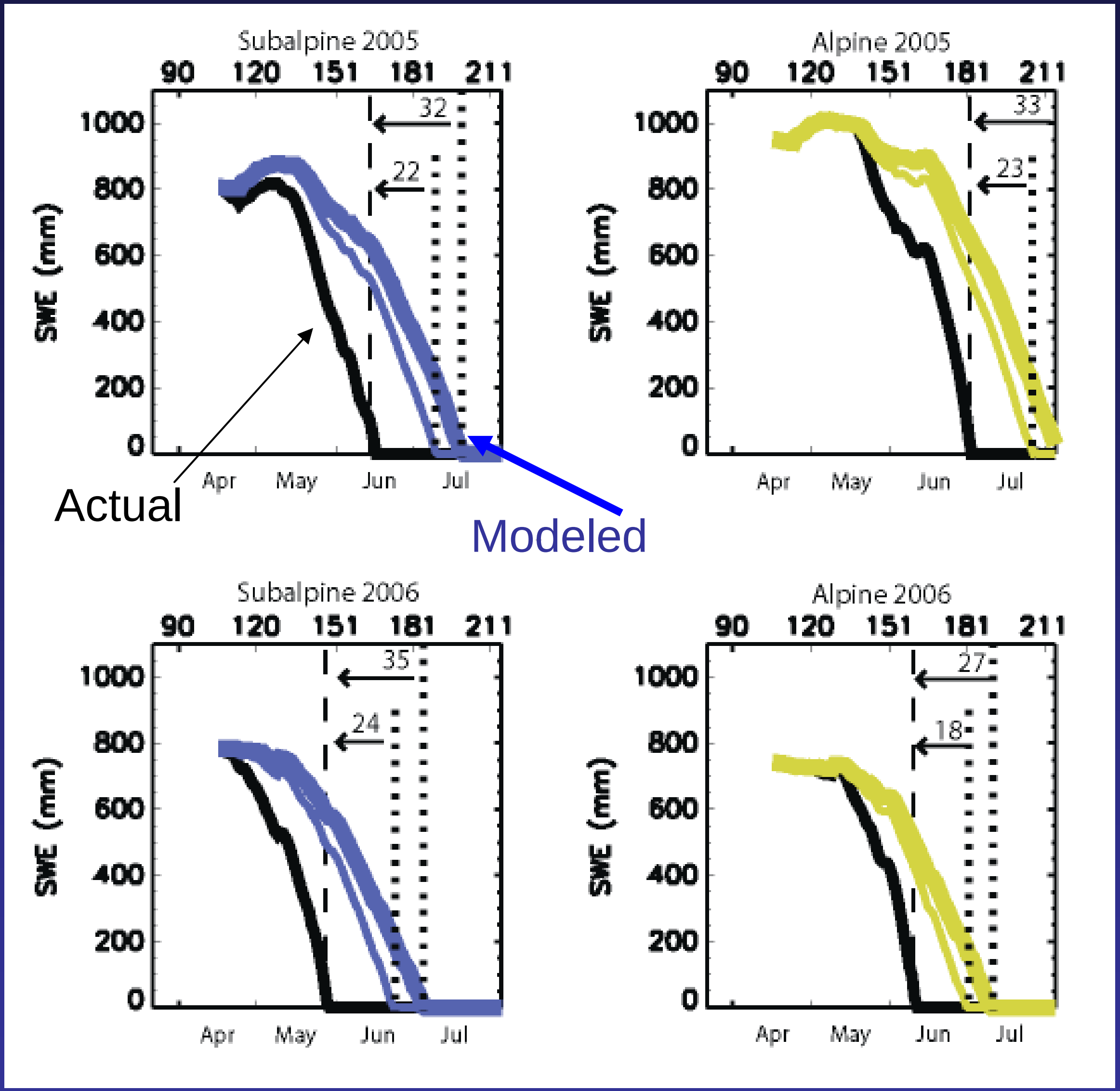
Phil Pasteris, NRCS

2006 Snowpack Vanishing Act



Phil Pasteris, NRCS

Actual and Modeled Snow Melt Dates, 2005 and 2006



SNOBAL

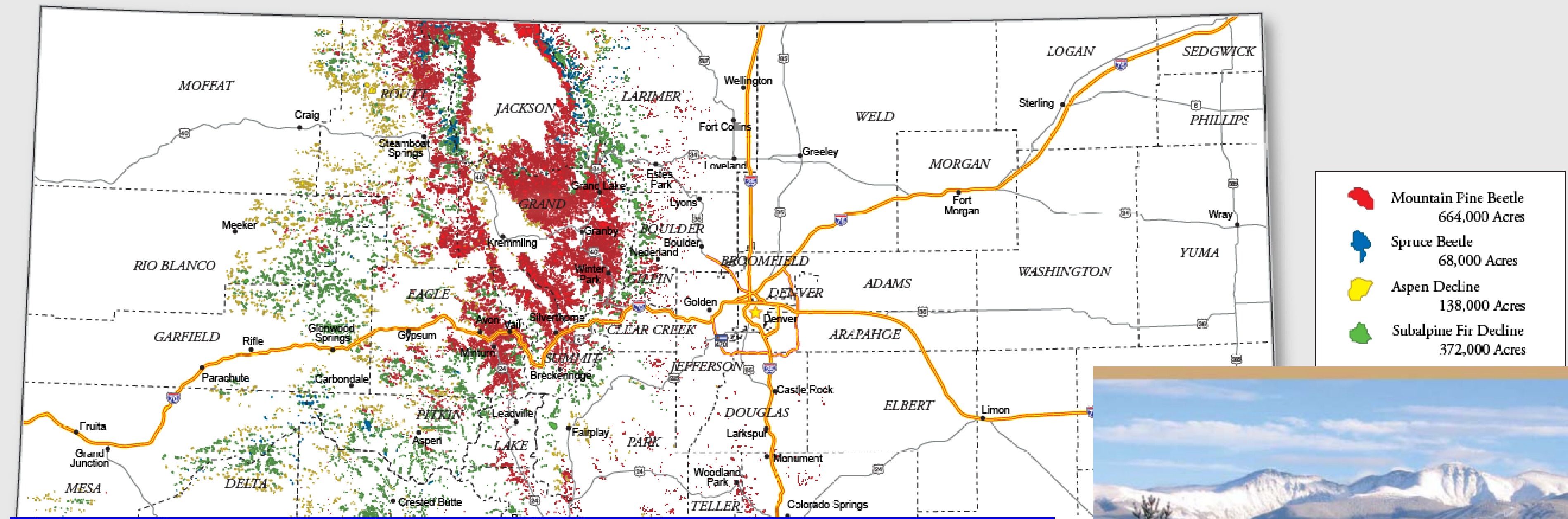
Marks et al (1998)

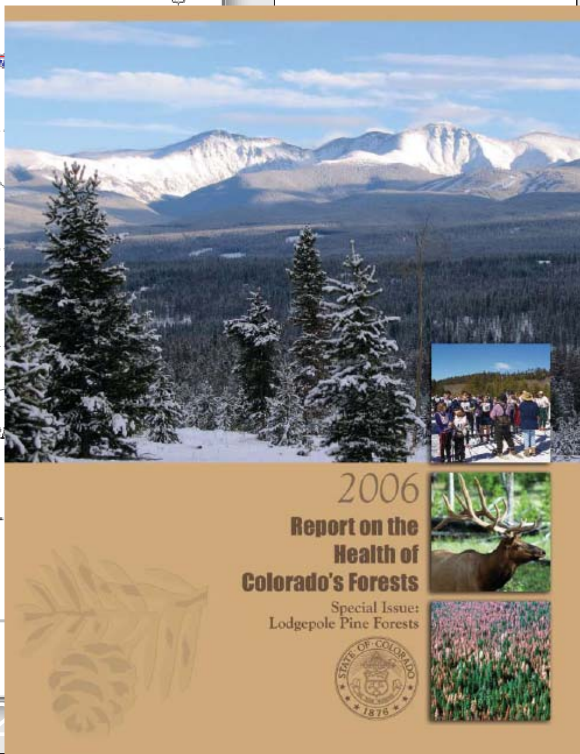
Driven by complete energy balance measurements at SBBSA

Radiative effects of dust removed on hourly basis

Wild Cards: Pine Beetles

Colorado's Forest Insect and Diseases in 2006



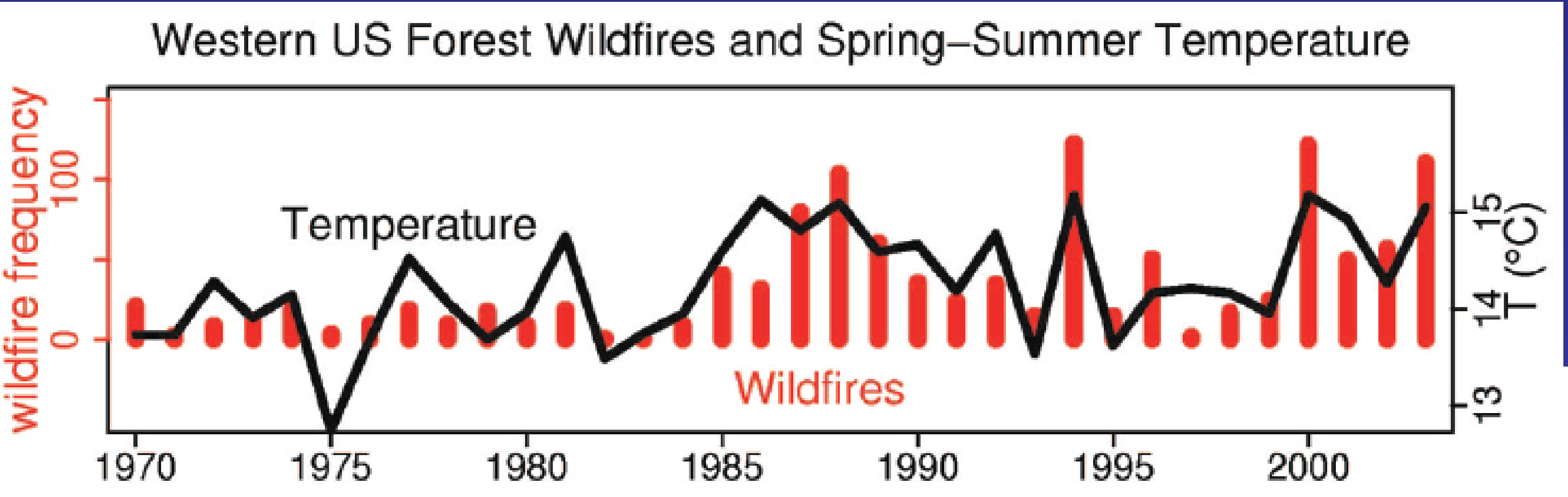


- Infestations are part of a natural cycle but consider:
- 1000 Square miles infested in Summit and Grand Counties.
- Up to 90% loss of Lodgepole Pine in next 10 years
- Warmth allows pests to have 2 life cycles/year
- Absence of winter killing temperatures
- Combination of Fire Management and climate causes
- Debate over enhanced fire danger

“Warming and Earlier Spring Increases Western US Forest Wildfire Activity”

- Database of large wildfires in Western US since 1970 created
- Large fires increased dramatically in the mid 1980s – Compared to 1970-86 average
  - More Total Number of Fires – 4x
  - Total Area Burned – 6x
  - Longer Lasting Fires
    - from 7.5 days to 37 days
  - Longer Fire Seasons –
    - 68% or 76 days, half of increase at begin, half at end
  - Fires strongly tied to spring and summer temperatures
- Most of increases in N. Rockies, CA, not CO
- Note: Hayman and Buffalo Creek have cost Denver Water Millions of $

- **“The greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks, and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.”**
- **Westerling et al. Science, 2005**



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"I'm starting to get concerned about global warming."

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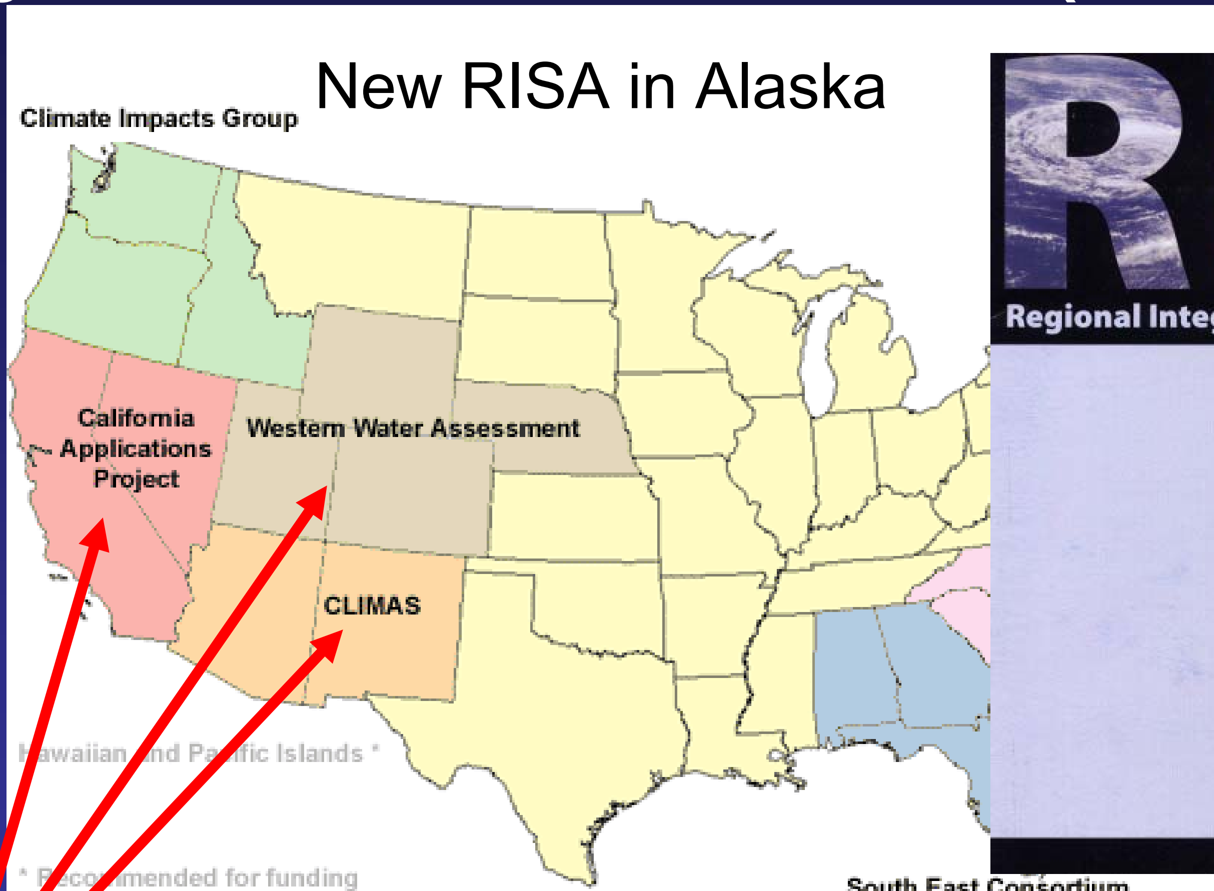
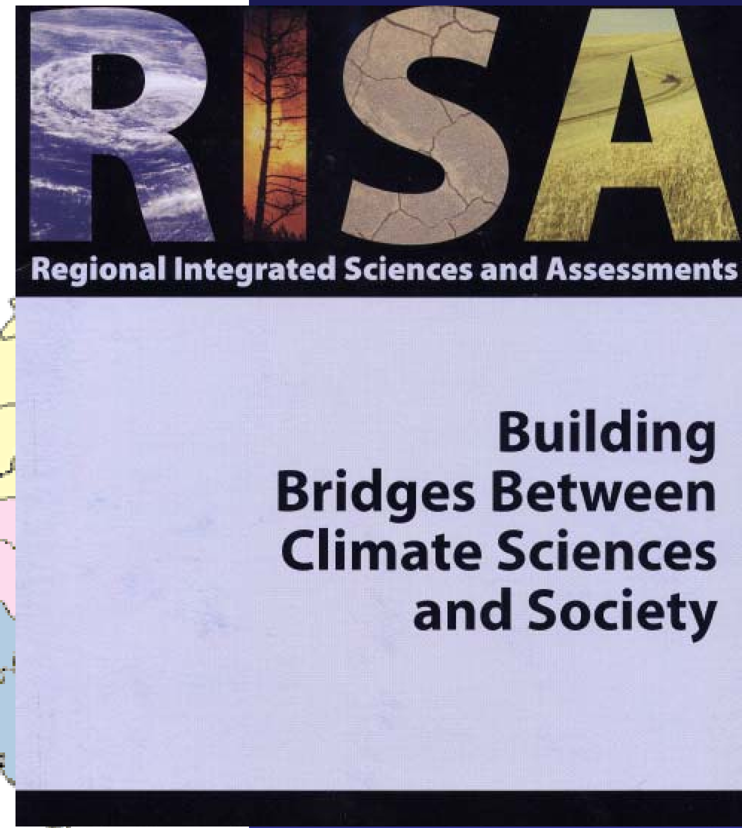
Western Water Assessment one of 8 Similar NOAA Regional Integrated Sciences and Assessments ("RISA") Programs.





3 RISAs are located in the Colorado River Basin

http://www.climate.noaa.gov/cpo_pa/risa/

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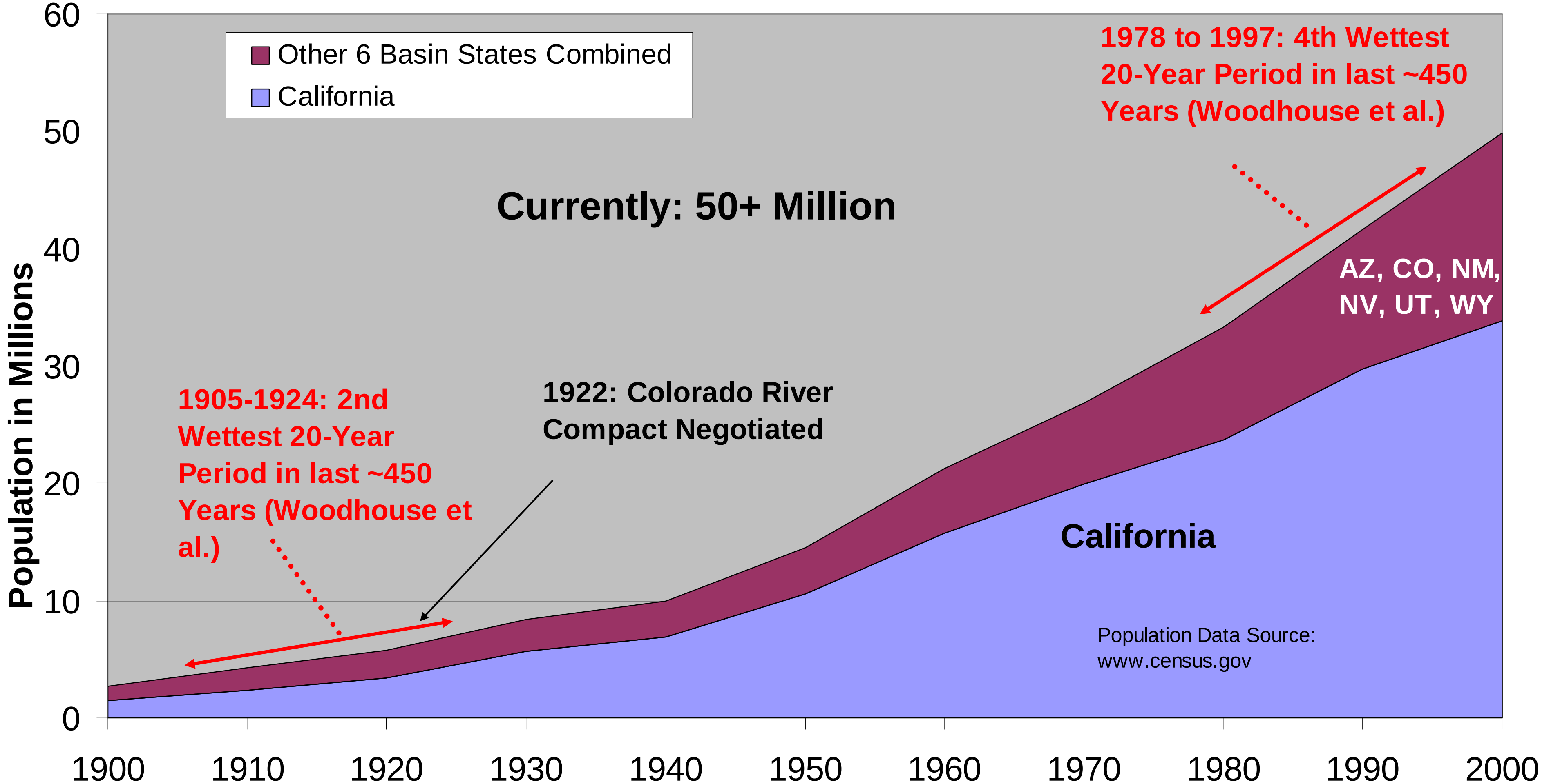
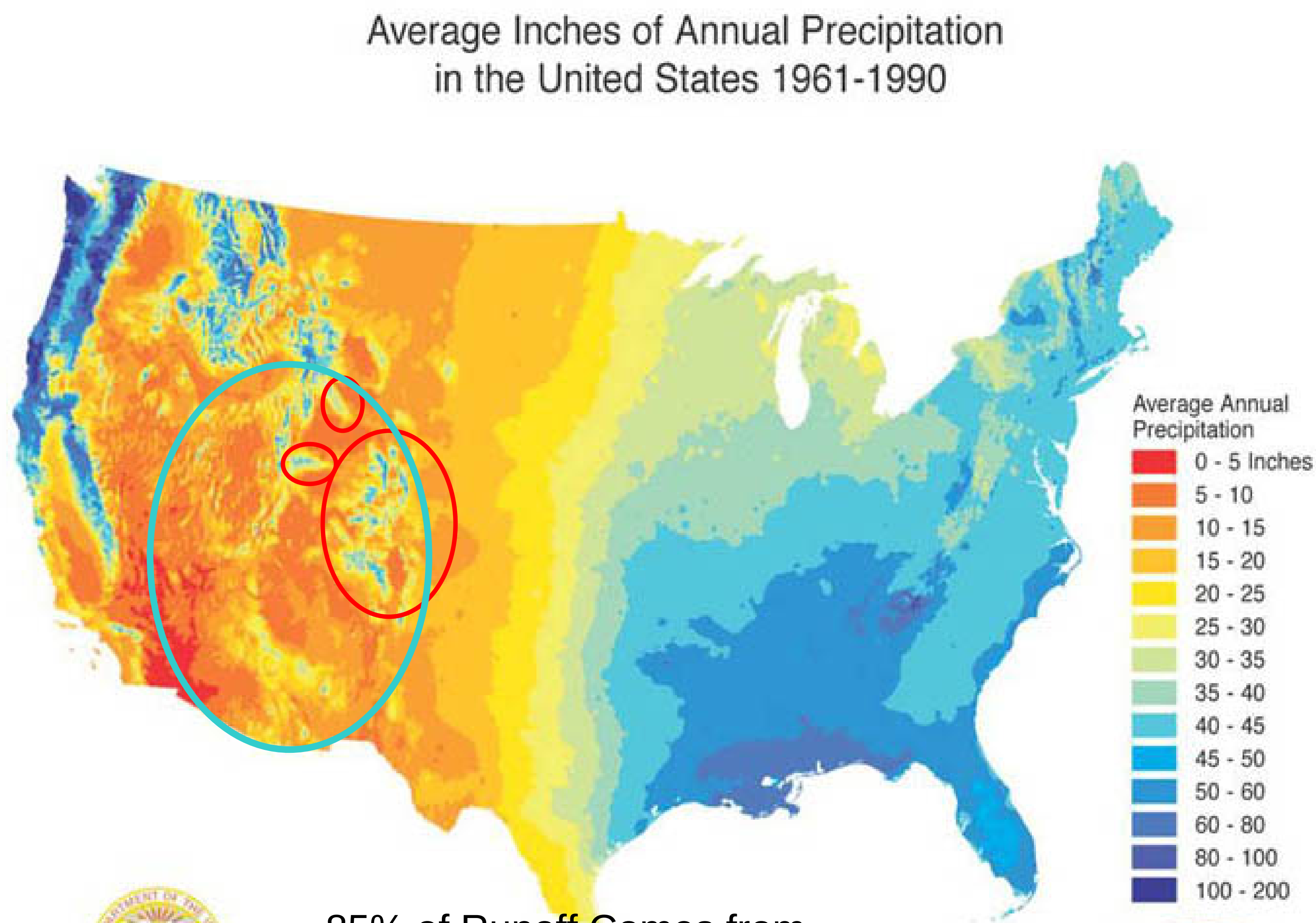
Colorado River Basin Overview

Source:Reclamation

- 7 States, 2 Nations
- Fastest Growing Part of the U.S.
- Over 1,450 miles in length
- Basin makes up about 8% of total U.S. lands
- 60 MAF of total storage
- Highly variable Natural Flow which averages 15 MAF
- Irrigates 3.5 million acres
- Serves 30 million people
- Very Complicated Legal Environment

Population Growth of Colorado River Basin States 1900-2000

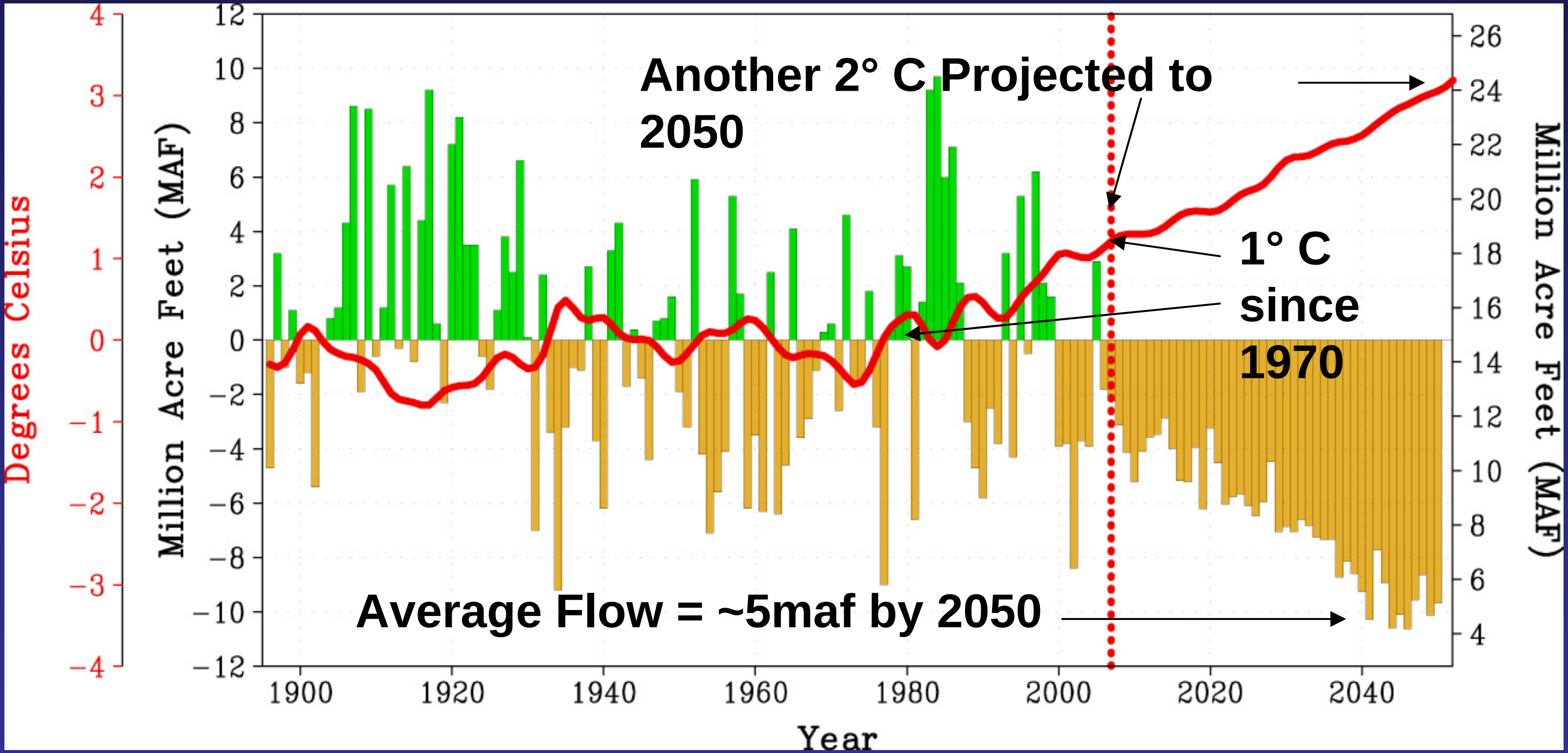




85% of Runoff Comes from
15% of Colorado Basin Area

Source: USDA-NRCS: http://www.ftw.nrcs.usda.gov/prism.html

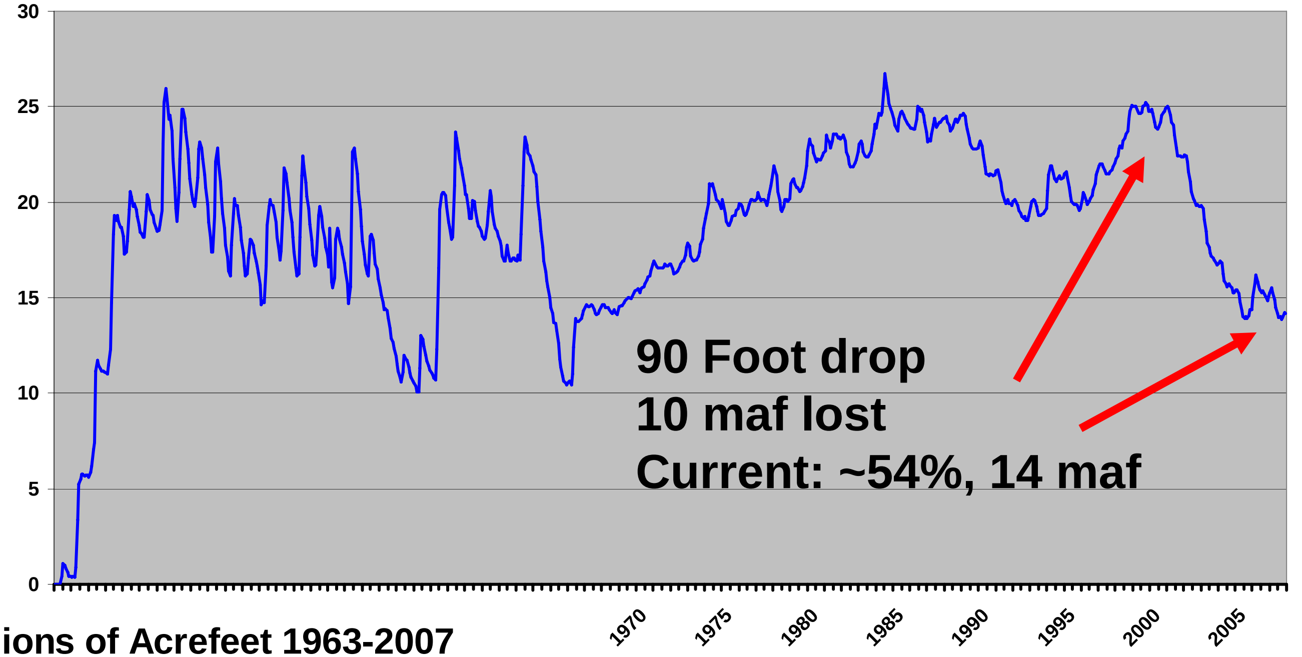
Hoerling and Eischeid Eye-Opening Results



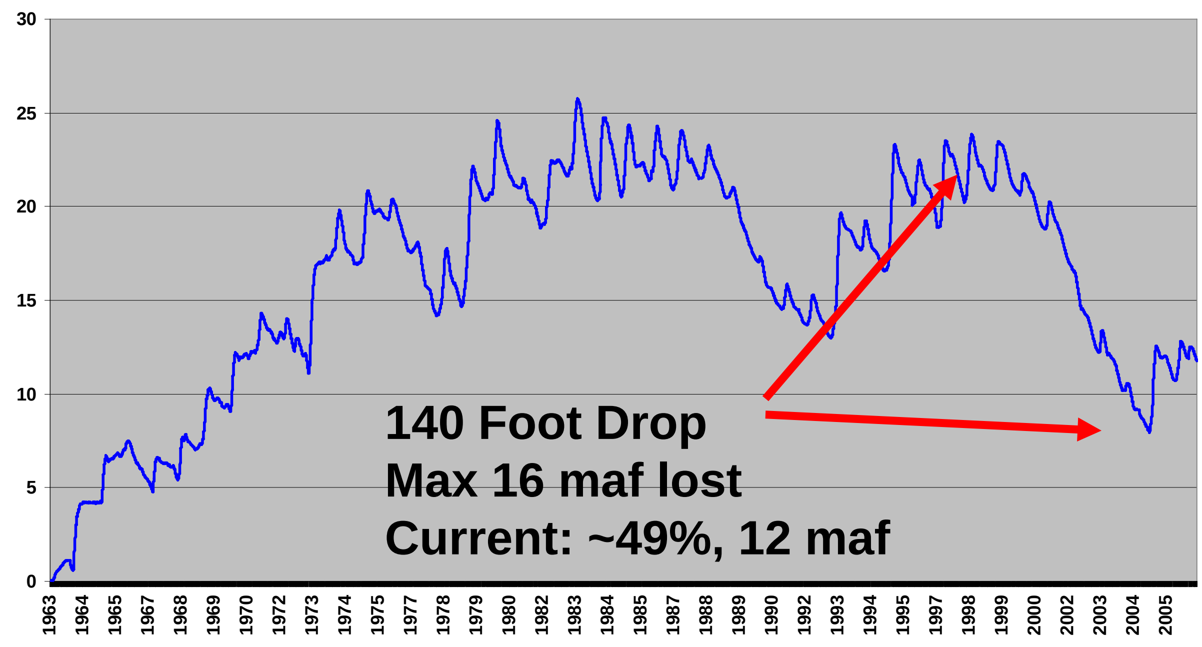
Article at: wwa.colorado.edu/resources/climate_change.html
Christensen et al and Wolter/Doesken Colorado Temps as well

Declining Lakes Mead and Powell

Lake Mead Volume in Millions of Acrefeet 1935-2007



Lake Powell Volume in Millions of Acrefeet 1963-2007



5 Years of 10 maf/yr
66% of average flows
Worst drought in historic record

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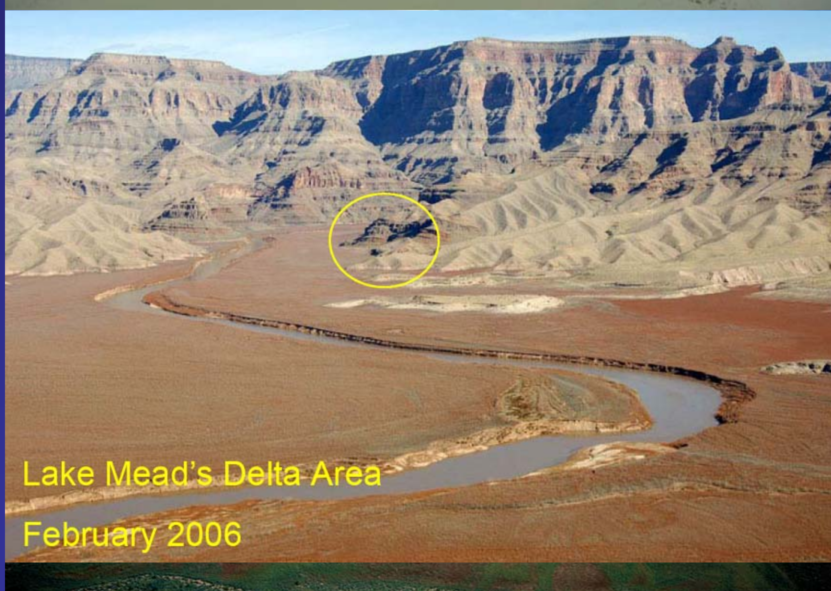

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Source: USGS, Reclamation

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A Current Problem in the Lower Basin

- Avg Lake Mead Inflows = 9.0 maf
  - 8.23 maf from Powell (Current Operating Rules)
  - 0.77 maf tributaries below Powell
- Avg Lake Mead Outflows = 10.4 maf
  - 7.5 maf LB States (4.4 CA, 2.8 AZ, 0.3 NV maf)
  - 1.5 maf Mexico
  - 1.4 maf Evap + Delivery Losses
- Net Balance = -1.4 maf/year
  - (Mead at 14 maf now)

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A Lurking Problem in the Upper Basin

- How Much Water Left to Develop?
  - Current uses: ~4.7maf per year
  - At 13.5 maf avg , ~0.5 maf left to develop
  - At 15.0 maf avg, ~1.5 maf left to develop
- ‘Hydrologic Leftovers’ Creates Uncertainty
- Upper Basin Compact penalizes for overuse, but only determined after the fact
- Terror over Compact ‘Call’ Ramifications

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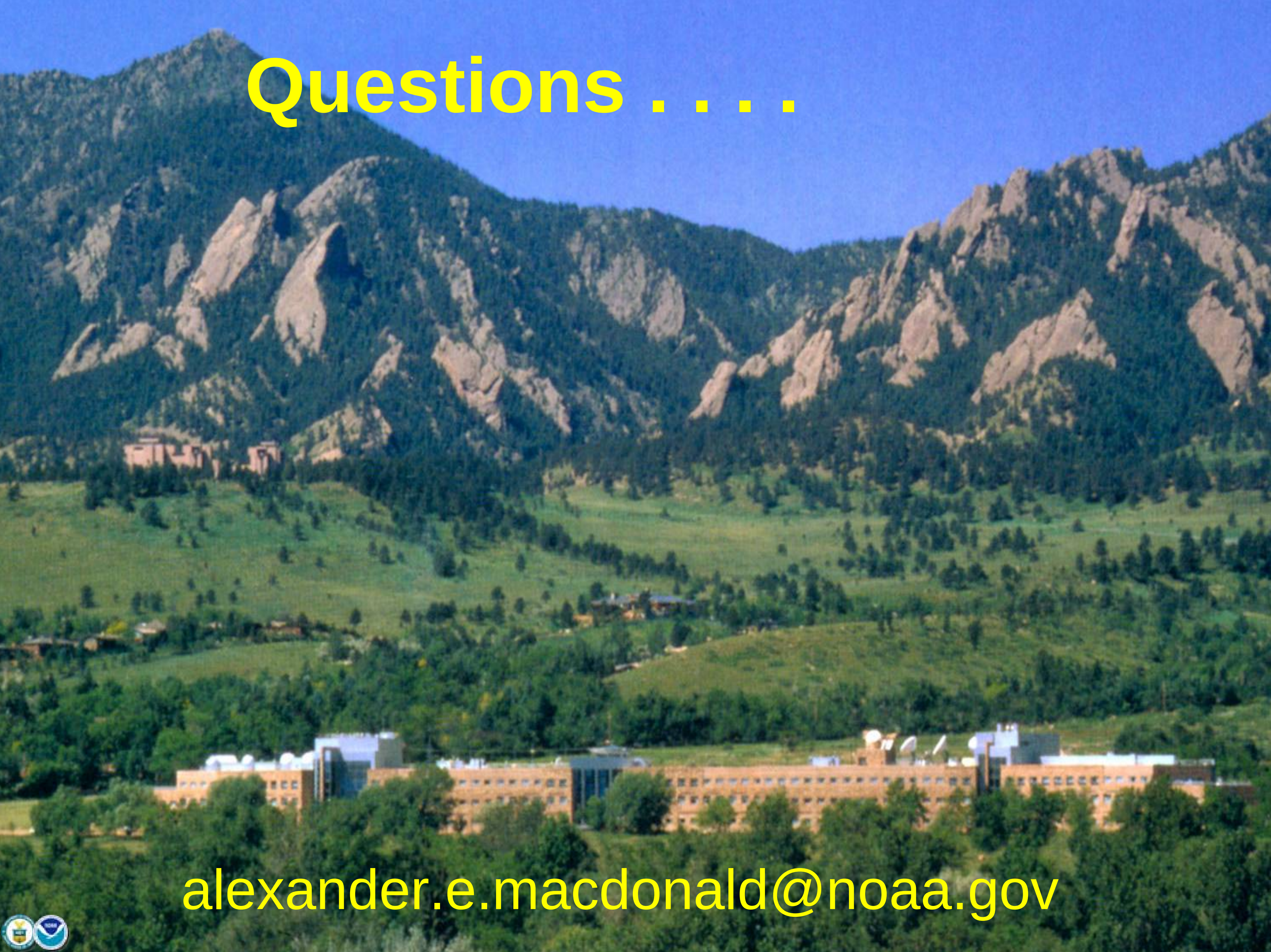
Concluding Thoughts

- Population Stresses as important as climate in the West
- Recent drought likely a combination of natural variability plus added climate change signal
- Changes in snow water equivalent, fires, beetles, temperatures, runoff dates now apparent in parts of the West
- Natural variability will continue and likely be enhanced
- Managing and Reducing Risk key to Future Water Management
  - Assess Vulnerabilities First, Then Climate
    - Minimize Known Risks
  - Models important, but used with thought
  - Decision makers need to insist that CCSP address decision support issues
  - Relook at Yield, Flood, Other 'Stationarity' Assumptions
  - Demand the Best Data Possible – NOAA, USGS, USDA
  - Selected Research opportunities to reduce unknowns – e.g. Colorado River
- Collaborative Opportunities among USGS, Reclamation, NOAA exist
  - CLIVAR Post Docs
  - Future Colorado River Flow Uncertainty Reduction
  - Water 2025 Update based on Climate?
  - National Integrated Drought Information System

Questions . . . .



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